

Beneath Bass Strait: Linking Tasmania and Mainland Australia using Ambient Seismic Noise

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SUMMARY

One of the most hotly debated topics in Australian geology pertains to the tectonic relationship between Tasmania and mainland Australia. The focus of this study is ambient seismic noise data from 24 broadband stations, which span northern Tasmania, several islands in Bass Strait (King Island, Deal Island and Flinders Island) and southern Victoria, thus providing a dense coverage of surface wave paths that can be exploited to image the 3-D structure of the crust joining Tasmania and Victoria in high detail. The new results of this study will address fundamental questions regarding Tasmania's tectonic provenance and its enigmatic relationship with the mainland. Furthermore, they will impose important constraints on the broad scale geology of a highly prospective region that hosts significant hydrocarbon deposits. To produce the highest quality Green's functions, careful processing of the data has been performed, after which group and phase velocity dispersion measurements have been carried out using a frequency-time analysis method on the symmetric component (average of the casual and acasual signal) of the empirical Green's functions (EGFs). The location of the experiment is such that the cross-correlations produce strong signal down to 1s period, thanks to the proximity of microseisms in Bass Strait and the Southern Ocean. Group and phase dispersion measurements from the EGFs have been inverted to obtain Rayleigh-wave group and phase velocity maps at different periods, which are expected to shed new light on the structure beneath Bass Strait.

Key words: Bass Strait, ambient seismic noise, surface wave tomography.

INTRODUCTION

Reconstruction of the tectonic setting of eastern Gondwana between Australia and Antarctica requires a solid understanding of the relationship between several structural elements in both SE Australia and Northern Victoria Land. One of the key pieces needed to solve this puzzle centers on the tectonic relationship between Tasmania and mainland Australia.

Studies that attempt to link Victoria and Tasmania have been wide ranging and have undergone considerable change through time, leading to a variety of plausible, although often

incompatible and conflicting, tectonic models (Elliot and Gray, 2002; Cayley et al., 2002; Direen, and Crawford, 2003; Berry et al., 2008; Cayley, 2011; Gibson et al., 2011). One of the main difficulties in reconciling mainland Australian and Tasmanian tectonics is the lack of Precambrian exposure in the Lachlan Orogen (Victoria), which contrasts with the West Tasmania Terrane that exhibits numerous outcrops of Proterozoic rocks (Elliot and Gray, 2002), apparently excluding any tectonic affinity between them. Furthermore, the West Tasmania Terrane differs significantly from the East Tasmania Terrane in that the latter does not contain any evidence of Precambrian rocks and no evidence of a Proterozoic continental basement has been reported, either in outcrop nor inferred from geophysical surveys (Williams, 1989; Reed, 2001; Young et al., 2011). Perhaps most significantly, the presence of Bass Strait and the Mesozoic and Cainozoic sedimentary and volcanic sequences that mask the older terranes, makes the link between Tasmania and southeast mainland Australia even harder to decipher. This has significantly impeded the ability of conventional surface mapping to unravel the tectonic history of this area, which remains one of the great challenges of Australian Earth sciences.

In this study, ambient noise tomography is carried out using passive seismic data that has been exploited to construct high resolution tomographic images of the shallow to deep crust beneath Bass Strait, which play a vital role in elucidating the structure between Tasmania and Victoria.

METHOD AND RESULTS

The data used in this study is sourced from a network of broadband seismometers, which was firstly deployed in approximately mid-2011 as a collaborative effort between the Australian National University (ANU), FrOG Tech, Mineral Resources of Tasmania (MRT), University of Tasmania (UTAS) and Geoscience Victoria (Figure 1). Although they are still recording, one year of data is currently available. The Bass Strait deployment allows a dense coverage of surface wave paths extracted from ambient noise recordings that can be exploited to image the 3-D structure of the crust joining Tasmania and Victoria in high detail. Moreover, it completes the high resolution passive seismic coverage of southeast Australia that has been undertaken over the last decade by multiple institutions (principally ANU).

The use of ambient seismic noise to extract information about Earth structure is relatively new. The potential of the approach was first revealed by Shapiro & Campillo (2004), who successfully demonstrated that Rayleigh waves emerge from the long-term cross correlations of background seismic energy.

Subsequently, detailed images of the lithosphere structure in various parts of the world have been obtained by exploiting this class of data (Shapiro & Campillo, 2005; Yang et al., 2007; Bensen et al., 2009; Arroucau et al., 2010; Young et al., 2011; Saygin & Kennett, 2010, 2012). It turns out that long term cross-correlation of the background noise recorded at two stations produces an estimate of the Rayleigh surface wave (from the vertical component or Love wave from the horizontals) packet (known as the empirical the Green's function) that is equivalent to the signal that would arrive at one station if the source waveform were a delta function located at the other station. Therefore, the principal requirement of this technique is that at least two instruments are simultaneously recording. The main source of ambient noise typically originates from oceanic disturbances, although anthropogenic and atmospheric effects also contribute. The attractiveness of ambient noise tomography is that path geometry and density are almost entirely controlled by the receiver configuration. Both depth sensitivity and lateral resolving power are frequency dependent, although for the latter, the path coverage generally plays an important role in dictating the minimum permissible resolution. Typically, the shallowest structures that can be resolved through this novel type of tomography lie at about 2-3 km depth (generally deeper for anthropogenic noise), whereas the deepest structure that can be imaged reside in the lower crust (30-40 km depth).

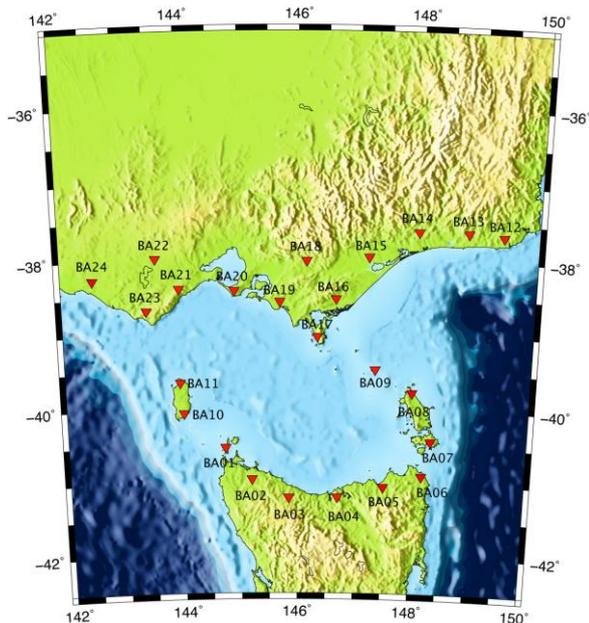


Figure 1. Bass Strait deployment. Inverted triangles represent instruments.

To produce the highest quality Green's functions, careful processing of the data is required. To this end, a scheme similar to that applied by Bensen et al. (2008) was employed. From one year of data, it essentially involves dividing day-long records into approximately 54 minutes segments with 400 seconds overlap. Segments that contain anomalously large amplitudes, either from earthquake signals or instrument errors, are removed prior to applying a bandpass-filter between 0.01 and 2.0 Hz to the data. Subsequently the vertical- component is cross-correlated and stacked for all possible station pairs, which produces the empirical Green functions. Figure 2 shows how a clear signal can be retrieved from the cross-correlations.

Group velocity dispersion measurements were then performed using the frequency-time analysis method of Levshin et al. (1972) on the symmetric component (average of the casual and acasual signal) of the empirical Green's functions. After this, phase velocity was measured using a modified version of the image transformation technique described by Yao et al. (2006). Once both group and phase velocity dispersion is measured, a tomographic inversion was performed over a range of periods to generate a series of group and phase velocity maps. This process has been carried out using the surface wave tomography software FMST described in Rawlinson et al. (2008). Once this process has been completed it will be possible to generate a 3-D shear wavespeed model by extracting phase velocity dispersion curves from the maps generated for all different periods on a horizontal grid of nodes. Separately inverting these models for 1-D shear velocity and then joining the results together will produce a composite 3-D model.

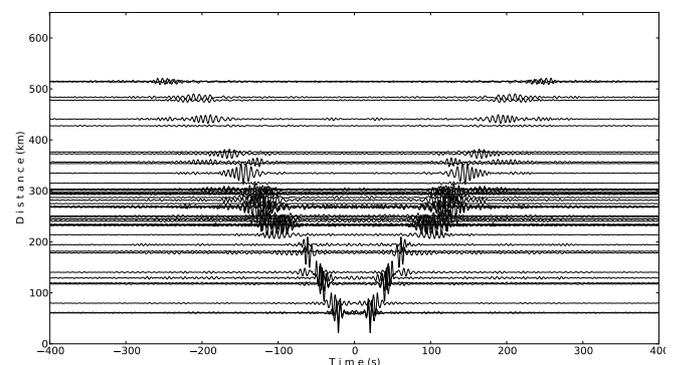


Figure 2. Record sections showing all the possible cross-correlations combinations associated with station BA01 and BA02.

A resolution test based on synthetic data is performed. This makes it possible to investigate solution robustness, which is dependent on path coverage and data noise. Here, this is done by applying the so called synthetic "checkerboard test" (Hearn and Clayton, 1986; Glahn and Granet, 1993; Rawlinson and Sambridge, 2003), which involves using an identical source-receiver path configuration to the observational dataset to predict traveltimes for a predetermined checkerboard structure defined by a pattern of alternating high and low velocity anomalies. An example of this is shown in Figure 3, along with a group velocity map taken from the solution model at 10 s period. Clearly, the quality of the recovered checkerboard is generally good in the center part of the model, although smearing is present in peripheral areas of the velocity model, particularly to the northeast and northwest. Due to the preliminary nature of the results that have been produced so far, a detailed analysis of the structural and tectonic implications is yet to be produced. However, the fact that we observe distinct low velocity zones in the neighborhood of both the Bass Basin and the Gippsland Basin, suggest that these early results are headed in the right direction.

CONCLUSIONS

We present the first ambient noise tomography of the Bass Strait. Using data from a total of 24 stations surrounding the area between Tasmania and Victoria, high resolution Rayleigh wave group and phase velocity maps have been produced, which reveal the nature of the crust lying at shallow to mid-

crustal depths. Future work will focus on refining the data processing technique, more comprehensively reassessing solution robustness, using more sophisticated Bayesian transdimensional tomography methods to generate a 3D shear wave model, and interpreting the results together with information provided by potential field data, geochemical analysis and field mapping.

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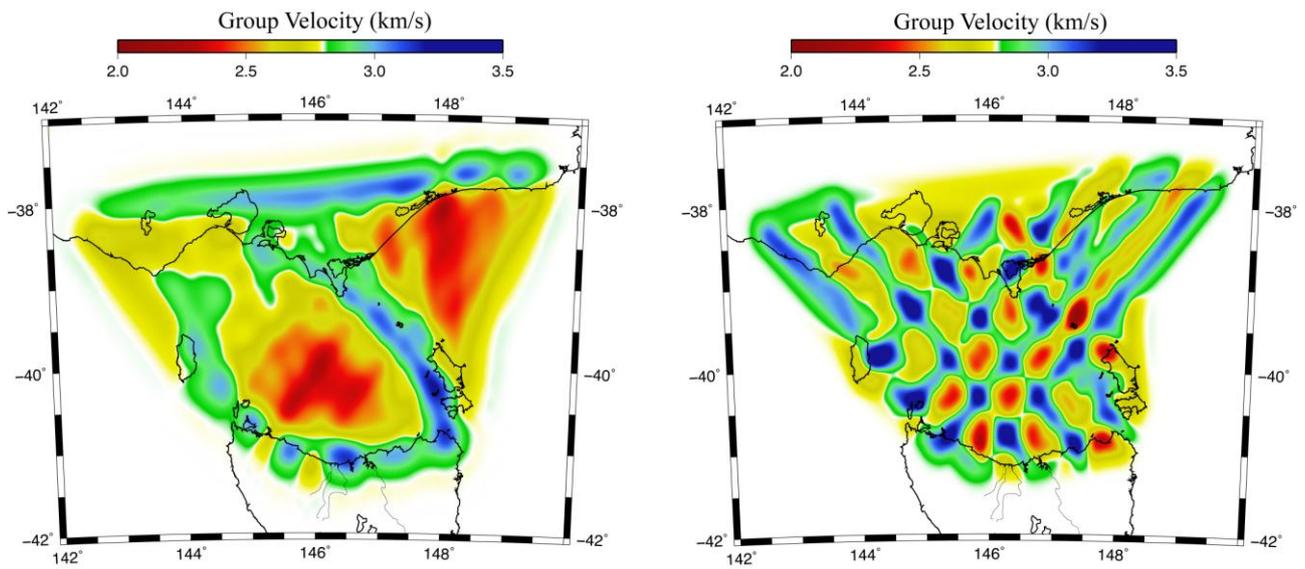


Figure 3: Group velocity map (left) and checkerboard resolution test result (right) for Rayleigh waves for 10 s period.